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HIGHWAY LIGHTING RESEARCH

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SYNOPSIS

The development of the use of sodium vapor as an illuminant and its application to street and highway lighting is discussed. The use of this new source of light will mean many changes in present practices and the research engineers are working on the problem of its most efficient use. The sodium lamp derives light from the passage of an electric current through a vapor of sodium with a small quantity of Neon gas. When the current is turned on the lamp first glows red as the Neon gas carries the arc and then turns gradually to a golden yellow as the sodium vaporizes. The process is fully described. The application of the lamp to highway lighting is then considered from the standpoints of "On what does the effective seeing of an object depend?" "How must the sodium vapor illumination be applied?" "What are its visual advantages?" The relation of various kinds of road surfaces to lighting problems is brought out, and the possible future economies that may be realized are discussed. Two demonstrations in New Jersey as in accord with the Illuminating Engineering Society's Code are described and illustrated.

Even during these past years of economic stress when the expenditure of dollars and even of cents has been very carefully balanced by the value received, there has been in many parts of the country a growing appreciation of the value of adequate street and highway illumination as a safety and saving factor in the affairs of the general public. Recently has come the announcement that sodium vapor as an illuminant has been developed to such a point that actual demonstrations may be made in order not only to study its practical application, but also to study its relative desirabilities and limitations as compared to our present modern illuminants.

For many years the Research Laboratories have labored with the problem of developing more efficient light sources. Hand in hand with this problem have gone the allied problems of engineering development, economic analysis, application studies and the visual reactions of the "human seeing machine." Unfortunately, the acceptance of adequate illumination as well as the acceptance of many other developments having to do with human welfare has lagged materially behind the developments worked out by the research and application engineers.

We are indeed standing upon the very threshold of a new and better era in illumination of streets and highways for we now may combine not only the possibilities of potential application and generative efficiencies, but we now also have the realization of the economic advantages of good illumination as well as the fact that we are but "human seeing machines" and react according to the facilities which are provided.

In order to develop a sound structure upon which we may build our future store of knowledge and appreciation of sodium vapor as a highway illuminant, the subject should be divided into six parts.

1. The scientists' developments applied to present conditions.
2. How is sodium vapor used as an illuminant?
3. Why does sodium vapor radiate light?
4. Upon what does the effective seeing of an object depend?
5. How must sodium vapor be applied and what are its visual advantages?
6. What economies may the future hold for the ultimate consumer?

SCIENTISTS' DEVELOPMENTS APPLIED TO PRESENT CONDITIONS

The maximum efficiencies and advantages of many scientific developments are not made immediately available to the general public, if these developments depart radically from used and accepted equipment. There has always been a general resistance of the public to adopt quickly major changes. If the new developments necessitate entirely new equipment, there are major economic considerations which must be properly evaluated. For example, in the automotive field, the lowered wind resistance of the "tear-drop" design has been known. This year, however, is the first that we have seen any commercial companies even approximating this shape. In the field of illumination, we are all familiar with the slow change that has taken place in the candelabra type of luminaire and the acceptance of adequate and proper illumination from indirect and localized sources.

Manufacturers do the great proportion of research and development. Their activities are dictated to a considerable extent by commercial expediency. Revolutionary developments are very slowly applied to public benefit, on account of the cost and public inertia.

The research laboratory developments of high efficiency light generation through sodium vapor must be tempered by the fact that this illuminant, revolutionary as it is, is but a step forward from that of tungsten sources. Therefore, the engineer must give due consideration in his developments to the existing 100 volt range multiple systems and 5 to 7 ampere range series systems as are generally found here in the United States. He must compete with the simplicity of auxiliary operating devices of the incandescent system as well as its instantaneous starting characteristics and stability of intensity. In addition, in order to use efficiently the sodium vapor lamp of low intrinsic brilliancy and large physical dimensions, for highway lighting, he must combat the antiquated though extensively used systems of low mounted pole top units with the light source placed at one side of the road (see Figures 1 and 2). These are all conditions which militate against the most efficient application of the high efficiencies developed in the laboratory lamps.

HOW IS SODIUM VAPOR USED AS AN ILLUMINANT?

The sodium lamp derives light from the passage of an electric current through a vapor of sodium rather than from a tungsten wire; therefore,



Figure 1. Efficient Light Application 6000 Lumen Lamps—20-Ft. Mounting Height—151-Ft. Linear Spacing. 6-Ft. Bracket. Asphalt Pavement. Note how the specular reflection practically covers the entire traveled roadway.



Figure 2. Inefficient Light Application. 10,000-Lumen lamps—13-Ft. Mounting Height. 173-Ft. Linear Spacing. Lamps 3 ft. back of road surface. Asphalt Pavement. Note how specular reflection does not cover traveled road surface. Lighting conditions would be even worse than indicated on a straight-away.

as with all gaseous conduction lamps, it has the fundamental characteristics of an arc lamp resulting in the need of devices for limiting

the rise of current. Generally a system of a cathode and two anodes or two cathodes and two anodes is employed in an evacuated bulb (see Figure 3). A carefully measured quantity of pure sodium and a small

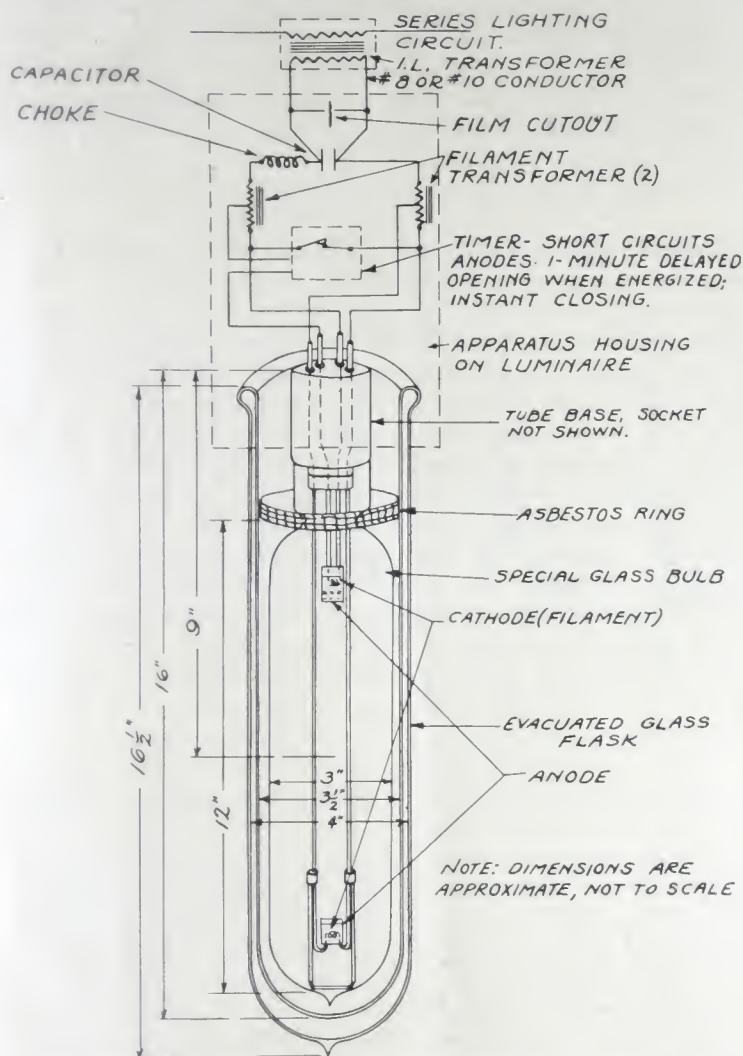


Figure 3. Schematic Diagram, 10,000 Lumens A.C. Sodium Lamp. With Series Transformer.

quantity of Neon gas are placed in the globe which is of special sodium resisting glass. When the cathode is heated by a low voltage external circuit and a potential applied between the anodes and cathodes, the lamp glows first red, as the Neon gas carries the arc, turning gradually

to a golden yellow as the sodium becomes vaporized in sufficient quantity. In this latter state the light is essentially monochromatic, falling close to that portion of the spectrum which provides the greatest retinal sensitivity. It is believed that this quality of radiation will remain practically as we have it today, due to the inherent sodium vapor characteristics. However, it is anticipated that the equipment used for generation and distribution of light will be further simplified even in the light of the great simplification that has already been realized to date.

THE PRODUCTION OF LIGHT FROM A GAS

To obtain a clear yet simple picture of this most interesting phenomenon we must presuppose a particular set of conditions in order to arrive quickly at the critical point of emission of radiant energy recognized commonly as light. In the most simple form of sodium vapor tubes, we have the evacuated glass enclosure with a low pressure Neon gas content, plus a definite amount of metallic sodium. At one end of the tube is a simple anode and at the other a cathode consisting of materials which freely produce electrons when the cathode is heated through application of voltage across its terminals by a separate source. In order to obtain sufficient sodium vapor in the tube, the Neon gas are is struck by application of proper voltages between anode and cathode, producing sufficient heat to vaporize the sodium. When this point is reached the sodium are strikes and the voltage between the anode and cathode is reduced to the operating level. This voltage level must be sufficient to provide accelerating voltage for complete ionization and yet low enough to prevent the destruction of the cathode by bombardment of the positively charged sodium ions. We then find a condition of free electrons being released from the heated cathode attempting to travel to the anode through a space (plazma) partially filled with positively charged sodium vapor atoms in equilibrium with their negatively charged electrons traveling in their accustomed orbits.

The production of light from a gas is brought about by its bombardment with electrons emitted from the hot cathode. When the velocity of the colliding electron is less than a certain value, critical for each gas, the electron simply bounces off suffering a change in direction but causing no disturbance in the atom which it strikes. If the velocity of the electron exceeds the critical value it may give up a definite amount of its energy to the atom. An atom with this extra amount of energy is said to be excited. When this extra energy is given up on the return of the atom to its normal state, the energy is given up as radiation, the wavelength of which depends upon the magnitude of the energy transfer at the time of collision.

If the energy of the impinging electron is still higher than in the case just described other excited states may be produced. The energy

radiated as the atom returns to normal through each of these stages is characteristic of the state in which the transfer is taking place. This accounts for the finding of more than the D lines upon spectral analysis.

When the energy of bombarding electrons is in excess of another critical value called the ionization potential, the atom may be completely disrupted into a positively charged nucleus or positive ion and a second electron.

Electrons on passing through a gas may then do any of three things:

1. Suffer an elastic collision with no appreciable loss of energy.
2. Excite gas atoms which give up their energy later in the form of radiation.
3. Ionize gas atoms producing positive ions, thus neutralizing the electron space charge and rendering the space more conductive.

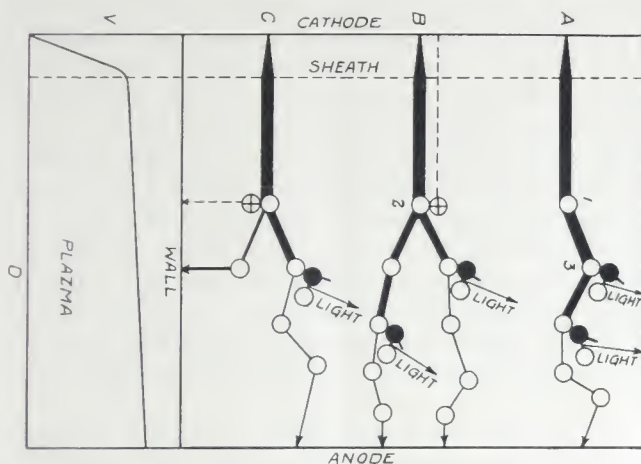


Figure 4. Schematic Diagram Illustrating Production of Light from a Gas

In the usual gas discharge the applied potential is concentrated within a very short distance of the cathode leaving the remainder of the space practically field free. The distribution of potential between electrodes is shown at the bottom of Figure 4. The region of high voltage drop is known as the cathode sheath and the remaining region which, as mentioned above, is practically field free, is called the plazma. The electrons from the hot cathode are accelerated by the voltage drop in the cathode sheath and then travel through the plazma with practically no further energy increase. In other words, the potential energy of the supply voltage is converted into kinetic energy of electrons in the cathode sheath. As the electrons diffuse across the plazma this kinetic energy is dissipated in the production of excitation and ionization of the gas atoms. The energy consumed by excitation is later given up as radiation while the positive ions and the slow speed electrons

(the products of ionization) diffuse to the walls where they recombine and give up their energy in the form of heat.

When the sodium lamp is first started the discharge is wholly Neon and the processes taking place are those described above. The heat resulting from this raises the bulb temperature and vaporizes sodium. When this occurs the electrons in the plasma also collide at times with the sodium atoms causing excitation of the latter which in turn produces light.

Sodium has the unique characteristic that most of the visible radiation is resonance radiation. That is, most of its visible radiation results from the return of its excited atoms to normal from the lowest energy level. The wavelength of this radiation is close to the region of maximum retinal sensitivity. These two facts, high percentage of resonance radiation, and the high retinal sensitivity to that wavelength, make sodium light production at very high efficiencies possible.

Fortunately about 75 per cent of the visible energy is radiated in the yellow or D bands of the spectrum. The reason that this is fortunate can only be explained by a discussion of vision.

In Figure 4 the energy of the electrons is shown diagrammatically by the width of the line representing its path. The electron at A collides elastically with a gas atom of 1 and bounces off in a new direction. Its collision with an air atom at 3 results in excitation of the atom and a reduction in the energy of the electron. After a second excitation its energy is below the minimum excitation potential and it has only elastic collisions throughout the remainder of its path. The excited atom at 3 returns to its normal state and emits a quantum of light.

The remaining two electrons at B and C produce excited atoms and also ions. The ion produced by the electron (B) moves back to the cathode counteracting electron space charge while that found by (C) together with an electron is shown diffusing to the walls. The recombination of ions and electrons at the walls is one of the sources of heat in the arc discharge. This production of heat is one of the barriers in practice to obtaining laboratory efficiencies near theoretical maximums.

ON WHAT DOES THE EFFECTIVE SEEING OF AN OBJECT DEPEND?

Doctor M. Luckiesh of the Lighting Research Laboratories of the General Electric Company at Nela Park in his "The Applied Science of Seeing" has classified the major factors on which visibility of an object depends into eight parts:

1. Its size or usually the size of certain critical details. In a printed letter, for example, the size of critical details is about one-fifth of the overall size of the letter.
2. Its distance from the eyes. This datum combined with the physical size of the object is usually expressed as minutes of visual angle.

3. Its contrast with its background.
4. Its brightness or that of its background which depends upon the reflection factors and the intensity of illumination.
5. The time available for seeing.
6. The ability of the eyes which depends upon their freedom from defects or the correctness of glasses.
7. The ability of the "human seeing machine" which depends upon such factors as intelligence, experience, reaction, concentration and application.
8. Various other visual and lighting factors such as glare, adaptation, and the color, brightness and pattern of surroundings.

In discussing the relative merits of sodium vapor as an illuminant, the item of contrast of an object with its background, as well as the object's brightness or that of its background, and the element of glare, are those which may have most weight in deciding the relative advantages of one illuminant over another.

Increased visual acuity has undoubtedly received more attention from the press than any other factor associated with this new illuminant. However, due to the particular monochromatic character of sodium radiation, it has been generally conceded that the big field for this new illuminant is for highway lighting and perhaps some fields of inspection where color discrimination is not a factor. In highway lighting, however, visual acuity is not the great factor because visual acuity is generally defined as the ability to distinguish fine details. This is an essential of good lighting and good vision, but undoubtedly has been over-emphasized in the discussion of seeing. When discussed in conjunction with highway lighting, its exact importance is not definitely known, and at present is considered not of greatest moment. It may be conceded that visual acuity under sodium illumination is of greater advantage under low levels of brightness than high levels. The levels to date, however, that have been investigated are still higher than those levels we are accustomed to dealing with in highway illumination. In this field of illumination, our vital interest is not in the detail of an object, but is there an object in our pathway which will provide a hazard. Information on this matter is being gathered as rapidly as possible.

HOW MUST SODIUM VAPOR ILLUMINATION BE APPLIED AND WHAT ARE ITS VISUAL ADVANTAGES?

The methods of discernment of an object upon the roadway regardless of the quality of illumination still will fall into four classifications (see Figure 5):

1. Discernment by direct illumination by adequate light falling upon the object.
2. By silhouette of the bulk of the object against a lighter background.

3. By discernment of revealing glints from polished surfaces on the object.
4. Discernment of the object's position by the shadow it may cast.

From the economic consideration of highway lighting which necessitates relatively low intensities at this particular day, the value of the silhouette effect is paramount. In order to obtain this desirable silhouette effect, we must produce road surface brightnesses of such values and in such positions so that an object between the light source and the driver will be adequately revealed. This desirable condition is brought about by installing the light sources over the traveled road-



Figure 5. Four Methods of Discernment—Direct Illumination, By Silhouette, Revealing Glints, By Shadow.

way at such a height to minimize glare and close enough together to provide an adequate brightness area above the horizontal to assist in overcoming the partial blinding effect of automobile headlights approaching the driver. In practice excellent results are obtained by use of specified positions as shown in Figure 6. A further factor which has not been given due consideration in the past is the placement of the light unit in such equipment as to provide a portion of the light on the road shoulder. This is essential for two reasons:

1. For illuminating any hazard which may be there or any object which may become a hazard, as a pedestrian stepping across the road (Figure 7).
2. To provide an area of brightness in which the eyes harassed by oncoming light may turn for relief.

This necessity of producing adequate road brightness brings up questions concerning contrasts—both color contrast and brightness contrast—as well as those concerning the advantages of various road

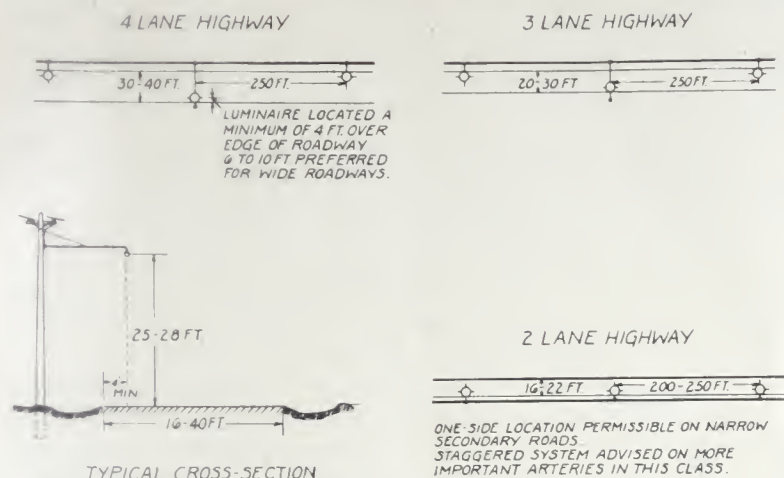


Figure 6. Diagram Showing Most Effective Placement of Highway Lighting Equipment.



Figure 7. Most Effective Equipment Placed in Most Effective Manner Reveals Pedestrian or Object on Road by Silhouette.

surfaces ranging from new, clean, light colored cement surfaces to black bituminous surfaces.

Color contrasts generally cease to exist under sodium vapor illumi-

nation and the advantage of color contrast, which is generally considerable, disappears. We must, however, discriminate between the advantages of color contrast and those of color discrimination. The latter in reality should not be considered because we are dealing with low levels of illumination at which point the eye in any case is not accustomed to distinguish color due to the fact that the illumination is so low that the cones of the retina are out of action and we are using only rod vision.

In studying the fundamental factors regarding vision it has been found that contrast is the most generally effective factor in seeing. It has been found that in intensity variations ranging from low values of artificial light to those of full daylight, the minimum size of an object which is just visible varies through a range of 3:1. With brightness contrast variations, however, this range in minimum size becomes 30:1. The brightness contrasts studied were those of very low value, to the highest which is represented by black on white.

Attempting to get accurate measurements on visual effects is just about as difficult as attempting to measure the length of a race track with a rubber band. Therefore, the careful experimenter is reluctant to give forth information until often-times the number of observations runs into the hundreds of thousands. However, due to the intense interest that has been displayed in sodium vapor illumination, Doctor Luckiesh and Mr. Moss have released some preliminary figures which may indicate the necessity for caution in making any statement which in the light of future developments may become rash. In order to study the influence upon contrast of sodium illumination one hundred and one specimens of colored paper, representing hues throughout the spectrum, including the purples with their varying tints and shades were selected. They were studied under equal intensities of illumination from sodium vapor lamps and tungsten filament lamps. After obtaining the reflection factors of these one hundred and one specimens, the determination of contrast of five thousand pairs becomes merely a mathematical procedure. We define contrast as the ratio of difference between the two brightnesses, divided by the higher brightness. A perfect black on a perfect white is a contrast of 100 per cent. Forty-two of the specimens under sodium lighting appeared brighter than under tungsten lighting and had an average reflection factor under sodium of 53 and an average under the tungsten of 45. Forty-two of the other specimens appeared brighter under the tungsten illumination, having an average reflection factor of 29 compared to their average reflection factor under sodium of 22. Seventeen of the specimens were approximately the same with an average reflection factor of 27.

Of the five thousand pairs that would be possible, combining the 101 specimens, report has been made upon the study of 595. This number has been sufficient to show again the general superiority of sodium light

over tungsten light in accentuating contrast. For example, 267 pairs exhibited greater brightness contrast under sodium light than under tungsten light. The average brightness contrast of these was 50 per cent under the tungsten light and 66 per cent under sodium light. One hundred and fifty-two pairs exhibited lesser brightness contrast under sodium light than under tungsten light. The average brightness contrast of these was 43 per cent under tungsten light and 29 per cent under sodium light. One hundred and seventy-six pairs exhibited brightness contrast varying within plus or minus five per cent so they were not included in the foregoing in which the difference in brightness contrasts was greater than five per cent under both illuminants. Such low contrast cannot play an important part in seeing. They are so low that quick and uncertain seeing must rely upon other factors.

In the problem of street and highway lighting, the question of road surfaces is coming more and more to the fore. It has only been during the past two years that lighting men in general have come to a realization of how dependent we are upon road surfaces for adequate or inadequate visibility. Mr. C. A. B. Halvorson's discussion of this problem is reported in the Eleventh Proceedings of the Highway Research Board, Part I, Page 399.

Three of the types of road surface in common use, on roads having sufficient traffic to warrant highway lighting, are portland cement concrete, bituminous macadam and sheet asphalt. These three are entirely different in their characteristics and act differently under fixed and portable lighting.

Visibility under street and highway lighting is, of course, an entirely different matter from that in the home or office. Under the ordinary lighting on our public thoroughfares, we are seeing at such low levels of illumination that it is impossible to see by direct light reflected from the object. For example, an object in the roadway may have from 0.05 to 0.10 foot-candle, falling on it, but with the object itself having a reflection factor of not more than 50 per cent and presumably as low as one and two per cent. The apparent intensity on the object is of the order of 0.001 to 0.05 foot-candle which is practically unnoticeable. Accordingly we are forced to rely on silhouette vision, in which foot-candle intensity plays no part. The only requisite for silhouette visibility is a lighted background against which the object can be seen in relief. From the physical aspects of the case, the lighted background must consist of the road itself and as such the sharpness of the silhouette is determined by the brightness of the road surface, and, as present tests may indicate, the spectral characteristics of the illuminant.

Each of the three types of road surfaces mentioned above has different characteristics under light. In the first place they reflect light differently. Sheet asphalt acts as a mirror or a water surface reflecting light in streaks or specularly. Bituminous macadam reflects as a

blotter does or diffusely scatters the rays in all directions. Portland cement concrete also reflects diffusely but the dispersion varies according to the roughness of the surface. However, both of the last two pavements reflect specularly when they become wet. The reflection factor for portland cement concrete is about 80 per cent while it is around 4 per cent for bituminous macadam and asphalt.

Since visibility under street and highway lighting is dependent on the brightness of the road surface it is interesting to compare the brightnesses of the three surfaces. Sheet asphalt possesses the highest brightness when the roadway viewed lies between the observer and the lamp, but the brightness (4 per cent of the light) is confined to a strip very little wider than the light source itself, although the strip may be more than a 1000 feet long. Thus if an object happens to be in line with the strip of brightness it is quite easily seen, while if it is to one side, it is as if in total darkness.

Bituminous macadam, reflecting diffusely, gives only a circle of relatively low brightness directly under the lamp since the 4 per cent reflected from it is dispersed in all directions. Accordingly a very large lamp is necessary to give a high brightness on such a road surface.

Portland cement concrete likewise disperses the light in all directions, which is an advantage in itself since the entire width of roadway thus becomes a background instead of the small strip of brightness present with asphalt or any pavement when wet. However, due to the high reflection coefficient of concrete, its brightness is high with a relatively small source of light.

Directly connected with this problem also is the action of these surfaces under automobile headlights. What is said above about the action of bituminous macadam and portland cement concrete under fixed lighting is also true of them under portable lighting since the driver is dependent on the amount of light reflected back to his eyes for vision. The headlights of oncoming cars should be less glaring on portland cement concrete than on a black road since the road surface is brighter making the contrast less marked. On asphalt pavement, as on all wet pavements, the light from headlights is reflected specularly away from the driver where it does little good.

It appears therefore that of the three types discussed portland cement concrete surfaces are the best and most economical from the standpoint of lighting. The objection that is sometimes raised because of sun glare can be surmounted by the use of sun glasses.

It is often proposed that with correctly adjusted headlights street lighting would be unnecessary. It may be argued however, that since under headlights, vision is dependent upon reflected light, under adverse conditions if the object is dark, having a very low reflection factor, there will be little reflected light and, therefore, no effective seeing. Likewise under oncoming headlights, the iris of the eye is contracted

and unless the road surface beyond the opposing headlights is bright, vision is too greatly handicapped for safety. The question of balance between the illumination of headlights and street lights causing an object of certain color to disappear has also been raised. This may happen particularly on very uniformly lighted streets, a method of lighting which is not the best practice. With non-uniform lighting, such a merging would be more difficult, and furthermore if the roadway is adequately lighted, there is no necessity for headlights of high enough intensity to cause such a balance.

WHAT ECONOMIES MAY THE FUTURE HOLD FOR SODIUM VAPOR
ILLUMINATION?

The peak of the relative luminostic curve of the eye is at the wave length of 5550 Angstrom units. If all of the energy supplied to a luminous tube were emitted at this wave length the luminous efficiency would be in the neighborhood of 668 lumens per watt. In the sodium lamp of today we find that the energy emitted in the infra-red line is about one-quarter of that emitted at the yellow D line. The summation of the remaining lines both in the visible and the ultra-violet region only amounts to a few per cent. The majority of light emitted from our sodium lamps is of the wave length of 5890 Angstrom units or about 78 per cent as luminous as the light at the peak of 5550 Angstrom units.

The heating losses, plus those which are incidental to the use of governing equipment due to the arc characteristics of the sodium lamps point to the approximate theoretical maximum of 320 lumens per watt. The practical limit that has been reached so far has been 70 lumens per watt. The discrepancy of the efficiencies shown by these two figures is accounted for by the losses in the tube due to heat production and heat radiation and generative equipment. It is very apparent from the progress made so far that we still have a long way to go in the producing of practical efficiencies higher than we have to-day. The efficiencies that are being obtained in practice in the demonstrations throughout the country are of the order of 40 lumens per watt.

Conservative or cautious as I may appear to be in speaking of the superiority of sodium for seeing on the highway, we still can become enthusiastic for the economies that may accrue through knowledge gained by greater experience. Certainly we can become most enthusiastic in considering the potential increased luminous and visual efficiencies, and the lessened cost of generative equipment and distribution equipment which undoubtedly will be lowered through the application of engineering ability and mechanical ingenuity.

The welfare of human beings is the ultimate objective of lighting whether the majority of us recognize this or not. Intelligent and skillful use of various aids for seeing is necessary. The development and

use of sodium vapor as an illuminant for our roads is but the outgrowth of the use of our past incandescent sources. Any discussion of economies that may be effected in the future must of necessity give due weight to the advantages and economies that accrue to the individual citizen. It must be conceded that the benefits and economies of scientific lighting are best revealed by controlled laboratory research.

Controlled laboratory research, in studying the behavior of automobile drivers upon the highways, either with or without the benefit of adequate and properly applied highway illumination is difficult. Individual accident reports as filed with the authorities may not be relied on as being 100 per cent accurate, particularly in the reporting



Figure 8. Daytime View of Intersection of New Jersey Route No. 6 and Parsippany Boulevard.

of how the accident occurred. However, a great number of reports covering a considerable period of time, may be relied upon as being indicative, or giving a close approximation of the actual history of the accidents on the highway. Reductions ranging from 30 to 60 per cent of night accidents have been reported in installations where accident history has been available before and after installing highway lighting.

A most interesting study is being made in New Jersey at the present time in conjunction with Commissioner Hoffman's Safety Educational program. Heavily traveled sections of road throughout the state were chosen for study. These sections were each one mile in length and were chosen for their known bad accident record as well as their type of road surface, topography of adjacent country and their inherent accident hazards.

Two such sections of highway have been lighted for six months with incandescent lamps and modern efficient equipment. One section is on New Jersey State Highway No. 6 at and adjacent to Parsippany Boulevard, which intersection is about four miles east of Dover, New Jersey. One portion of the section is bituminous macadam and the other Belgian block. This is a two-lane highway, with many curves and slight grades, due to the rolling character of the country in northern New Jersey. As generally found in New Jersey there is a narrow gravel shoulder averaging six to eight feet on either side of the paved portion of the roadway. Day and night views of the intersection are shown in Figures 8 and 9.



Figure 9. Safety Demonstration Lighting at Intersection of Route No. 6 and Parsippany Boulevard. Note illumination of entire roadway and shoulder.

The second section is in South Jersey where we find the characteristic of flat country. This highway is two lanes in width, of concrete construction, with an average of 15 feet of light gravel shoulder on either side of the paved portion of the roadway. Night and day driving conditions are clearly indicated in Figures 10 and 11. Six thousand lumen incandescent lamps are used in the highway proper and the illumination is built up at the intersection by employing 10,000 lumen incandescent lamps. Proper seeing conditions are provided by the employment of efficient refracting globes. Comfortable seeing conditions are produced by properly designed prisms in conjunction with a rippled effect on the outer surface of the clear glass globe, and the use of proper mounting height, spacing and road overhang, as discussed previously.

The accident history of New Jersey as reported in 1932 includes 45,867 accidents causing 31,426 injuries and 1,180 deaths. It is true that there is a concentration of traffic hazards in New Jersey and that there are more miles of improved and heavily traveled highways per



Figure 10. Safety Demonstration Lighting at Intersection of Routes Nos. 33 and 34 in New Jersey. Daylight.



Figure 11. Safety Demonstration Lighting at Intersection of Routes Nos. 33 and 34 in New Jersey. Night. Daytime sight distances are provided through engineered illumination.

unit of area than may be the average throughout the United States. Nevertheless, every state has many miles of similarly heavily traveled highways which should be studied in order that the elimination of hazards and accidents may be brought about quickly and surely.

All of us who drive at night realize the immediate feeling of relax-

ation and safety upon entering and driving upon a well-lighted stretch of road. It is difficult indeed to put a dollars and cents value upon that sense of security and freedom of the mind from the worries incident to driving without adequate vision. It is not so difficult, however, to quantitatively appraise the losses which are encountered by the general public through the lack of good vision at night. It is estimated by those who have made a study of the accident statistics and the accident causes throughout the country that nearly one-half of the total accidents that occur upon our streets and highways at night are caused in the main by inadequate vision through lack of illumination. At the same



Figure 12. Illumination at Old Bridge, New Jersey Traffic Circle. Illumination not only provides spectrum seeing conditions on the roadway, but also prepares driver in advance for making turns.

time it must be remembered that nearly one-half of the total number of reported accidents happen during the hours of darkness.

The worth-while economies that may be anticipated from the use of this or any modern illuminant cannot adequately be measured by the luminous efficiency of the source but must be measured by the degree in which the illuminants are put into actual use upon our roads and highways. The saving of human lives, the prevention of suffering due to pain of physical and mental hurt resulting from loss of our loved ones, the relaxation of nervous and muscular tension so essential in these days of high speed living, are all economies. The degree to which they may add to our sum total of economies largely depends upon the highway engineers, who study this problem and make proper recommendations in the true light of their findings.

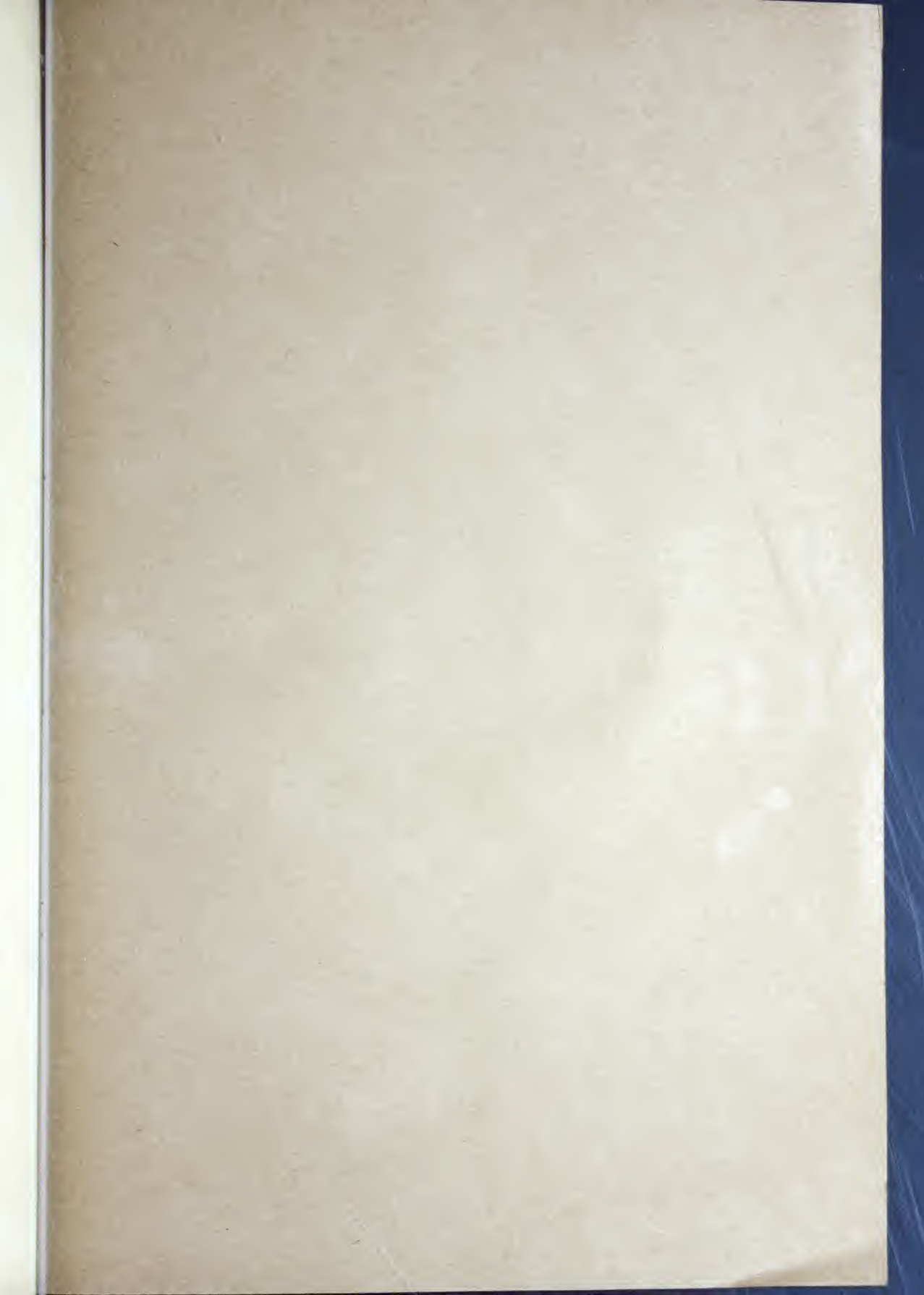
DISCUSSION
ON
HIGHWAY LIGHTING

MR. C. C. AHLES, *New York State Highway Department*: I observed the lighting at Schenectady and I thought you might be interested in the cost. It is quite an item, this cost of lighting highways: it is, in general, a difficult thing to put down as a lump sum but if highways were lighted so that it could be done upon a real production basis, the cost would not be more than perhaps \$1200 to \$1500 per mile per year—that is for real highway lighting.

MR. LOWE: Mr. Ahles' quotation of \$1200 to \$1500 per mile per year as the cost of highway lighting may be considered fair at the present time. These costs, however, have been based upon present street lighting schedules and rates. It is difficult indeed to speak of street lighting costs in a general way, as there are so many factors in various localities which might materially change the amount; such as the facilities already present, the proportionate distribution of costs to other types of consumers, the cost of maintenance which varies greatly when considering the number of lights to be taken care of; the width of the right-of-way, necessitating different types of equipment to get the necessary overhangs and mounting heights; the distance between units, energy charges, etc.

Motor Vehicle Commissioner Harold G. Hoffman of New Jersey has said: "It is true that proper and sufficient highway lighting would require an expenditure of considerable money. However, this expense, properly weighed against the benefits derived, including the saving of lives and the saving of millions of dollars, all of which is a part of the present tremendous economic loss, would, we feel, unquestionably show a saving of money to the tax payer who must ultimately foot the bill in either case."

One point I would like to stress is that when speaking of highway lighting, we are not speaking of illuminating all of our highways. It is only where there is economic justification for lighting. It is difficult indeed for the average man to realize the point of economic justification for the expenditure of the money necessary for adequate and proper highway lighting. This latter problem may be solved by analysis of accident records collected by motor vehicle departments, safety organizations, police departments, etc.



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